

# DEVELOPMENT OF SHORT WAVELENGTH INFRARED ARRAY DETECTORS FOR SPACE ASTRONOMY APPLICATIONS

NASA Grant NAGW-2868

Semiannual Report No. 5  
For the period 1 January 1994 through 30 June 1994

The Smithsonian Astrophysical Observatory (SAO) and its team -- the University of Arizona (UA), the University of Rochester (UR), Santa Barbara Research Center (SBRC), Ames Research Center (ARC), and Goddard Space Flight Center (GSFC) -- are carrying out a research program with the goal of developing and optimizing infrared arrays in the 2 - 27  $\mu\text{m}$  range for space infrared astronomy. This report summarizes research results for the period 1 January 1994 through 30 June 1994. Additional details may be found in the various technical documents and memos issued during the period. A list of these can be found at the end of this report (Attachment A).

## Band 1 Detector Array Development

SBRC continued development of the CRC-744 10 K optimized 256 x 256 pixel multiplexer and performed a series of process experiments designed to shed light on the detector processing problems seen in the last detector lot. The Critical Design Review (CDR) for the CRC-744 was held at Hughes Carlsbad on January 26, 1994. No major issues were uncovered in the review. Hughes was authorized to move into processing.

Starting materials and processes were selected to make best use of the knowledge gained from the SIRTf "MIPPER" CRC-696 processing runs. The following lot split was adopted:

Split	Number	Material
	11	Standard 5 $\mu\text{m}$ epi
2	4	2 $\mu\text{m}$ , highly-doped. old epi matl
3	3	2 $\mu\text{m}$ , lightly-doped epi (Lawrence)
4	3	3 $\mu\text{m}$ , lightly-doped epi (Lawrence)
5	3	High-doped/counterdoped (1.3 ohm-cm) material

Split 5 provides the possibility of yielding multiplexers which are well suited to operation at 30 K. As this report is written (9/94), processing is complete and apparently successful based on test devices from the wafers. Wafer probing will be done in late-September 1994. Yields will be known in October.

SBRC processed a forth lot of detectors after successfully completing three processing experiments designed to uncover the problems leading to the failure of lot 3 in its entirety. Lot 4 processing was begun in February. Lot 4 consisted of a mixture of well proven and new detector materials, including some from a new supplier, Firebird. None of these wafers yielded good detectors.

SBRC ran experiments to determine the cause and found that low-doped InSb was more sensitive to normal process variability than the higher doped material usually processed. A lower yield must be expected under current conditions for low-doped InSb than for higher-doped material. Since SBRC has excellent results with low-

doped material on other lots, including a previous SIRTf run, the yield is not expected to be zero. SBRC will process wafers in small quantities in the future to minimize risk to any one lot. SIRTf InSb Lot 5 is in process as of September 1994. The first results are expected to be available in October.

### InSb Detector Array Tests at University of Rochester

#### Evaluation of FPA131

FPA 131 uses a CRC-463 multiplexer optimized for operation above 25 K. A number of arrays were made using this multiplexer to evaluate the effect of InSb processing changes on detector performance.

The quantum efficiency as a function of wavelength was investigated for this array in order to determine the long wave cut-off as a function of position. In addition, the thickness of the array as a function of position was determined. Since the SIRTf InSb thickness specification of  $7 \pm 1 \mu\text{m}$  was set for 10K operation, and since at 30K the diffusion length is quite long compared with the thickness, thicker arrays are conceivable in order to increase the long wavelength cutoff.

This array varies in thickness from 6.5 to 9.5  $\mu\text{m}$ . This means that the cutoff wavelength can be determined as a function of InSb thickness. The ratio of QE at 5.5  $\mu\text{m}$  to that at 4.7  $\mu\text{m}$  varies from 0.35 at a thickness of 6.5  $\mu\text{m}$  to 0.45 at a thickness of 9.3  $\mu\text{m}$ .

If SIRTf sets the InSb focal plane at 26K, it might be advisable to increase the thickness specification, perhaps to as large as 20  $\mu\text{m}$ , in order to enhance the long wavelength InSb response.

In order to confirm that the CRC 463 multiplexer did not contribute appreciably to the gamma radiation events reported last quarter for FPA 131, a bare MUX was exposed to the same irradiance as FPA 131. Approximately 10% of the hits seen with FPA 131 could be attributed to MUX hits.

Clocking programs for the new CRC 744 multiplexer have been written, but require revision. The clocking is actually very similar to that for the CRC-463/365/590 muxes. Thus we anticipate only minimal changes in the CRC 463 clocking program for the CRC 744.

The FPA 131 array system was used in an observing run in late February - early March at WIRO. The new temperature of operation (26K) and clock settings (on voltage -7.5V) adopted on the last run, and later thoroughly investigated in lab tests, were utilized. Excessive hot pixels at 700 mV VBIAS were noted; 600 VBIAS was used. Late in the run, horrible anomalous striping was noted. No change in T, bias or clock improved it. It could not be reproduced back in the lab. The DSP Array Controller used at WIRO is a clone of our system: we later discovered that slightly shortening CTtime eliminated a similar problem (at WIRO). It is a concern for SIRTf that operating temperature, clock levels, and bias conditions changed on this array over time.

### Hughes 256 x 256 IBC (Band 2) Array Evaluation at Ames Research Center

ARC released a competitive RFP for second generation 256 x 256 Si:As IBC arrays

and has received viable proposals in response. They are under evaluation as this report is written. Selection is expected in late-fall.

ARC participated in the CRC-744 readout critical design review at Hughes Technology Center on January 26. Ames also evaluated devices from the related MIPPER (CRC-696) program. The two programs have similar cryogenic FET performance goals. Sharing of data by the two efforts will allow both to benefit from the discoveries of the other.

The CRC-644 256 x 256 Si:As IBC array was reinstalled in the dewar, and it was cooled and operated. Follow-on tests are designed to assist both SIRTf and WIRE, a potential Small-Explorer Mission, and will strive to accurately measure crosstalk.

The array operated nominally, after some months in storage. Some initial software bugs were corrected. A primary test objective is determining the level of crosstalk in the array. Good progress was made toward that goal. By the end of August a small external aperture was successfully imaged onto the array, containing most all of the flux within one pixel. They still haven't reached the predicted limits of the system. They have reduced the spillover flux to about one part in 15. The test configuration includes an external blackbody source, a 25  $\mu\text{m}$  diameter aperture, a cold quartz lens, and a cold 1.15  $\mu\text{m}$  interference filter. These efforts, to quantify crosstalk by producing a very small (short-wavelength) spot, will continue in September.

A technical memo describing results of testing of the Hughes CRC-696 low-temperature readouts was prepared. This describes data on the low-doped epi parts from Lot 2. As was reported before, the data indicate that the parts meet the stated goals for read noise ( $<30$  e- rms) and stability. Most of his testing was done at 4 - 5 K, although he also took data at 1.5 Kelvin, which indicated no significant change in noise level at the anticipated, low operating temperatures for the MIPS Ge:Ga detectors. The intermittent "spiking" behavior seen in the Ames tests remains unexplained.

### Instrument Optical Design and Packaging

We explored a variety of optical designs during the period directed at understanding the weight and volume characteristics of instruments with and without filter wheels and with reflective and refractive optics. We also initiated design of an instrument in support of a possible collaboration between SIRTf and a Japanese mission called the Infrared Imaging Survey (IRIS).

For the first, our studies showed that in general, instruments using filter wheels were lighter, smaller and simpler than equivalent designs without them. Cryogenic mechanisms may be a significant risk factor, however, and can add cost to a mission. Refractive systems were shown to be smaller and lighter than equivalent reflective systems but are more difficult to realize due to lack of knowledge of the materials' index of refraction at cryogenic temperatures.

For the Japanese mission, requirements were defined and initial design studies initiated. As this report is written, those studies are nearing completion and a preliminary report will be submitted to NASA in October. Additional information in these studies is available in the reports prepared during this period (see Attachment A) and in reports prepared by ATR.

ATTACHMENT A  
LIST OF TECHNICAL DOCUMENTS AND MEMORANDA RELEASED  
1 JANUARY 1994 - 30 JUNE 1994

IRAC93-107	"SIRTF Payload Working Group Meeting #3 at GSFC, May 25, 1993" Team January 1994
IRAC94-101	"SIRTF Science Working Group Meeting, 16-17 December 1993" Team January 1994
IRAC94-102	"SIRTF Short-Wavelength Mission Informal Design Report" Team February 1994
IRAC94-103	"SIRTF Peer Review Preview at the Jet Propulsion Laboratory, 24-25 January 1994" Team February 1994
IRAC94-104	"RFP to the University of Rochester for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF) and the development of array detectors for the camera" R.S. Taylor 2 May 1994
IRAC94-105	"RFP to the University of Arizona for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF) and the development of array detectors for the camera" R.S. Taylor 3 May 1994
IRAC94-106	"RFP to Ames Research Center for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF) and the development of array detectors for the camera" R.S. Taylor 2 May 1994
IRAC94-107	"RFP to Goddard Space Flight Center for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF)" R.S. Taylor 3 May 1994
IRAC94-108	"RFP to Evans Engineering for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF)" R.S. Taylor 3 May 1994
IRAC94-109	"RFP to Santa Barbara Research Center for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF) and the development of array detectors for the camera" R.S. Taylor 4 May 1994

IRAC94-110	"RFP to Hughes Technology Center for a Rough Order of Magnitude (ROM) estimate of costs for participation in "Phase A Concept Definition of an Infrared Array Camera (IRAC) for the Space Infrared Telescope Facility (SIRTF) and the provision of flight array detectors for the camera" R.S. Taylor 27 May 1994
IRAC94-111	"SIRTF Science Working Group Meeting 5-6 May 1994 at CALTECH" Team June 1994
IRAC94-112	"SIRTF/IRIS Collaboration Initial Exploratory Meeting/IRIS Mission Description, June 20-21, 1994, at the Institute for Space and Astronautical Science, Tokyo, Japan" Team June 1994
IRAC94-301	"Performance Requirements" (Si:As Status Review) Terry Herter 4 February 1994
IRAC94-401	"RFP to Advanced Technology Research to Study an Alternative Refractive IRAC Design", (augment to Contract SV3-63005) R.S. Taylor 11 January 1994
TM94-3001	"SUTR Transfer Function" R. McMurray, Jr. 3 June 1994

